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# C-isotope stratigraphy and paleoenvironmental changes across OAE2 (mid-Cretaceous) from shallow-water platform carbonates of southern Mexico

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ABSTRACT

The stratigraphic and geochemical record of the mid-Cretaceous (Cenomanian–Turonian) Oceanic Anoxic Event 2 (OAE2) has been studied in numerous Tethyan and proto-Atlantic hemi-pelagic/pelagic successions, but little data comes from nearshore carbonate successions from the proto-Pacific region. Here we present the results of a combined stratigraphic and $\delta^{13}C$ study of C–T platform carbonates from southern Mexico, which were deposited within the proto-Pacific. Two scales of sedimentary cyclicity are recognized. High-frequency peritidal and subtidal cycles (0.4–8 m) display little evidence of cycle-capping subaerial exposure and are not correlative between sections; these relationships suggest that the amplitudes of high-frequency sea-level changes were minimal during the peak mid-Cretaceous greenhouse. Longer-term transgressive-regressive sequences (18–40$^{+}$ m) are correlated between sections, and using $\delta^{13}C$ trends, can be correlated with sequences developed in northern Europe and India.

The Mexican successions were sampled at a high resolution (~10 ky) for stable isotopes (inorganic, organic carbon and oxygen), total organic carbon, insoluble residues, and trace metals. The $\delta^{13}C_{carb}$ curve matches global trends (including 6 distinct isotopic stages) permitting identification of OAE2 despite the lack of characteristic anoxic facies. Using the $\delta^{13}C_{carb}$ trends, we tie the previously identified ammonite, planktonic foram, and nannofossil biostratigraphy from England and the Western Interior seaway of Colorado into the Mexican sections. The initiation of OAE2, defined by an abrupt positive 3–4‰ $\delta^{13}C$ shift, coincides with a long-term sea-level rise, though the sedimentary expression of the deepening is no greater than that observed for any of the other sea-level events across the studied interval. OAE2 termination (transition from gradually decreasing to background $\delta^{13}C$ values) is not associated with a particular sea-level trend. Stratigraphic changes in insoluble residues (proxy for continental sediment discharge) across OAE2 are not correlative between sections and do not show consistent systematic relationships with $\delta^{13}C$ or sea-level variations, therefore do not support the hypothesis that OAE2 was associated with increased continental-derived nutrient influx. Two peaks in trace metal concentrations coincide with the abrupt increase in $\delta^{13}C$ ratios (onset of OAE2) and during the transition from elevated-to-decreasing $\delta^{13}C$ values (near the C–T stage boundary). These trends are similar to those recorded in coeval deposits of the Western Interior seaway, and are consistent with the hypothesis that OAE2 development was related to the release of reduced metals during the short-lived (<1 My) Caribbean oceanic plateau basalt eruption. In this scenario, oxidation of the metals depleted the existing low dissolved-$O_2$ concentrations and thermally-buoyant plumes of seawater enriched in biolimiting elements mixed with surface waters, stimulated primary productivity, and further reduced $O_2$ concentrations leading to widespread anoxia and a large positive $\delta^{13}C$ shift.

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## 1. Introduction

One of the most interesting aspects of mid-Cretaceous (~124–90 Myr) paleoceanography is the widespread occurrence of organic-rich deposits representing short-lived (<1 Myr) ocean anoxic events or OAEs (e.g., Schlanger and Jenkyns, 1976). Associated with these anoxic events are abrupt positive $\delta^{13}C$ excursions recorded in marine carbonates and organic matter, as well as terrestrial organic matter (e.g. Arthur et al., 1988; Hasegawa, 1997). One of the most widespread and best studied of these anoxic events is OAE2 occurring near the Cenomanian–Turonian (C–T) boundary. This event is associated with a decrease in $^{87}Sr/^{86}Sr$ isotope ratios (Jones and Jenkyns, 2001), an increase in trace metal abundances (Orth et al., 1993; Snow and Duncan, 2005), a well-documented extinction and turnover in

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planktonic and benthic marine organisms (e.g., Leckie et al., 2002). In addition, it overlaps in time with massive eruptions of submarine basalts in the Caribbean (Snow and Duncan, 2005). These combined characteristics and the fact that the effects of OAE2 are global in extent indicates that the processes involved in its development caused major perturbations in the ocean-atmosphere-biosphere Earth system.

Our understanding of the paleoenvironmental perturbations occurring during OAE2 relies mainly on pelagic to hemipelagic marine deposits from the Tethys, the narrow protoAtlantic, and the epicontinental Western Interior seaway. Only fragmentary evidence comes from the largest ocean, the proto-Pacific, and very little data come from nearshore settings (Davey and Jenkyns, 1999). The paucity of Pacific records stems in part from the loss of sea floor to subduction and poor drill core recovery. The scarcity of nearshore stratigraphic and isotopic records is due to unconformities associated with sea-level falls, variations in seawater chemistry related to freshwater input and/or elevated evaporation rates, and diagenetic alteration during sea-level change and later burial. In addition, correlation between nearshore and offshore/pelagic deposits presents challenges stemming from facies controlled biostratigraphy; i.e., nearshore biostratigraphic biozones are based on benthic foraminifers and/or bivalves and have wide ranges, whereas age control in pelagic facies are based on planktonic biozones of narrow-ranging foraminifera, nannofossils, and ammonites. Fortunately, the distinctive $\delta^{13}C$ signature across OAE2 provides a facies-independent tool for age control and correlation. Through such correlations, sections without independent age control can be tied to sections with more robust biostratigraphy, cyclostratigraphy, and ideally radiometric age constraints.

The scarcity of nearshore OAE2 records is particularly unfortunate because these depositional environments are the interface between open-ocean and terrestrial realms and potentially record important physical, biological, and climatic processes not readily detected in either pelagic or terrestrial deposits alone. These processes include changes in sea level, continentally-derived sediment, freshwater influx, nutrient supplies, fluctuations in wind-driven currents (waves, longshore, and coastal upwelling), and changes in abundance and diversity of nearshore benthic macrobiota.

The objectives of this paper are to 1) describe the stratigraphy, $\delta^{13}C$ trends, and trace metal concentrations of late Cenomanian–early Turonian nearshore carbonates deposited in the proto-Pacific Ocean of southern Mexico, and to 2) use the C-isotope stratigraphy to correlate the previously established ammonite, planktonic foram, and nannofossil biostratigraphy into the Mexican successions to assess the response of nearshore carbonate environments related to OAE2 changes.

## 2. Geologic setting and Cenomanian–Turonian stratigraphy

The study area in southern Mexico (Guerrero state) is located approximately 125 km south of Mexico City and 130 km north of Acapulco (Fig. 1). The mid-Cretaceous (Aptian through Cenomanian) Morelos Formation represents a westward-deepening carbonate platform (the Guerrero–Morelos platform), which formed on the margin of a fragment of continental crust (Acatlán Complex) and faced the proto-Pacific ocean (Figs. 1b, 2). The Guerrero–Morelos platform forms the southern portion of a large carbonate platform system, which bordered the western Gulf of Mexico during Albian–Cenomanian time (Wilson, 1990; Fig. 2b). The Guerrero–Morelos carbonate platform was over 250 km long and > 150 wide (non palinspastic distances) and lay at ~23–28 °N during the Cenomanian (Urrutia-Fucugauchi, 1988; Molina-Garza et al., 2003).

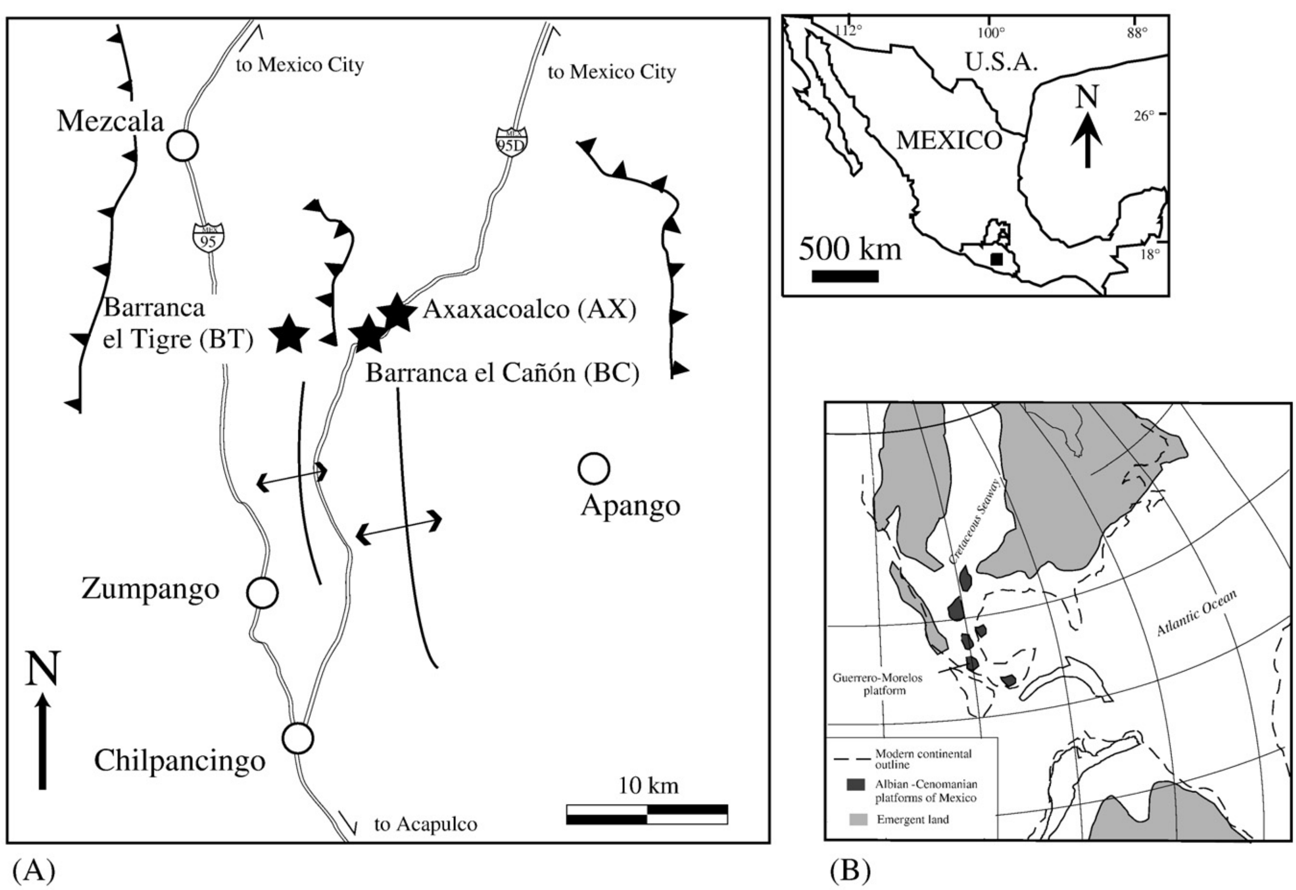


**Fig. 1.** (A) Location map showing study area in southern Mexico; inset shows the state of Guerrero (black box = study area). GPS coordinates: section AX = Zone 14Q, 0440422 mE, 1970014 mN, BT = Zone 14Q, 0445052 mE, 1968796 mN, BC = Zone 14Q, 0452468 mE, 1972121 mN. (B) Mid-Cretaceous paleogeography modified from Blakey website showing location of Albian–Cenomanian carbonate platforms rimming the Gulf of Mexico.